1.1.1.1.1.4 Chapter

5

5. Weather

5.1 Basic weather

Since weather plays such an important part on any CAP operation, the mission observer must become familiar with some basic weather conditions. Your ability to interpret weather conditions may make the difference between returning safely to base or becoming the object of the search.

Importance of Weather

- Weather is the determining factor in safety of flight. It will determine whether or not a mission can be flown.
- Weather can be the determining factor in navigation (getting to the search area and actually conducting the search).
- Weather can have a pronounced effect on how you conduct the search.
- Weather is a significant factor in the effectiveness of a search. This is reflected by its inclusion on the CAPF 104.

Your understanding of weather conditions is very important. Weather invariably affects the effectiveness of CAP missions. Flying missions under low ceilings and during severe turbulence can prove to be a dangerous undertaking. Constant vigilance on your part is essential to mission success and aircraft safety.

5.1.1 Sources of weather information

Sources of Weather Information

- National Weather Service.
- Flight Service Stations.
- Pilots during flight (PIREP).

5.1.2 Atmospheric circulation

The factor that upsets the normal equilibrium is the uneven heating of the earth. The earth receives more heat at the equator than in areas to the north and south. This heat is transferred to the atmosphere, warming the air and causing it to expand and become less dense. Colder air to the north and south, being more dense, moves toward the equator, forcing the less dense air upward. This establishes a constant circulation that might consist of two circular paths, with the air rising at the equator, traveling aloft toward the poles, and returning along the

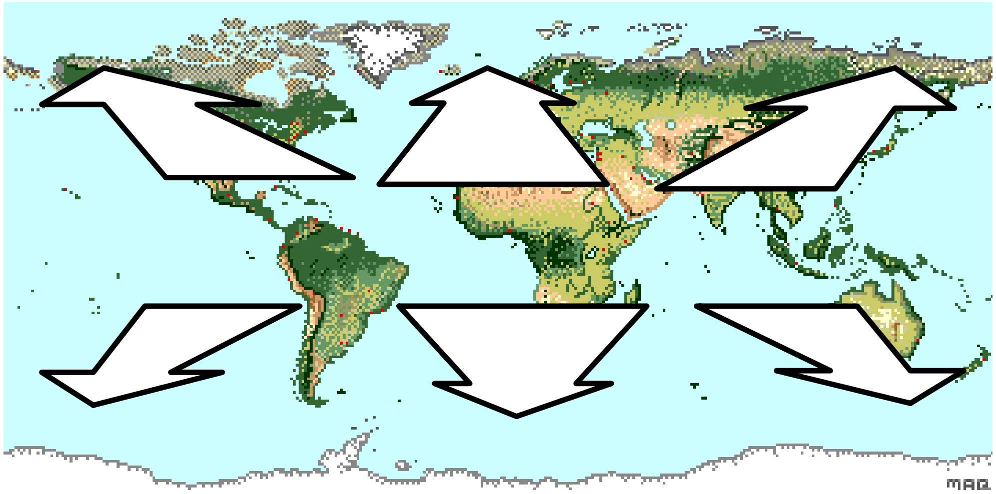


Figure 5-1

earth's surface to the equator. Heating at the equator would cause the air to circulate uniformly, as shown in Figure 5-1, if the earth did not rotate.

This theoretical pattern, however, is greatly modified by many forces. A very important one is the rotation of the earth. In the Northern Hemisphere, this rotation causes air to deflect to the right of its normal path. In the Southern Hemisphere, air is deflected to the left of its normal path. For simplicity, this discussion will be confined to the motion of air in the Northern Hemisphere.

As the air rises and moves northward from the equator, it is deflected toward the east, and by the time it has traveled about a third of the distance to the pole it is no longer moving northward, but eastward. This causes the air to accumulate in a belt at about latitude 30 degrees, creating an area of high pressure. Some of this air is then forced down to the earth's surface, where part flows southwestward, returning to the equator, and part flows northeastward along the surface.

A portion of the air aloft continues its journey northward, being cooled en route, and finally settles down near the pole where it begins a return trip toward the equator. Before it has progressed very far southward it comes into conflict with the warmer surface air flowing northward from latitude 30 degrees. The warmer air moves up over a wedge of colder air and continues northward, producing an accumulation of air in the upper latitudes.

Further complications in the general circulation of the air are brought about by the irregular distribution of oceans and continents, the relative effectiveness of different surfaces in transferring heat to the atmosphere, the daily variation in temperature, the seasonal changes, and many other factors.

Regions of low pressure, called “lows,” develop where air lies over land or water surfaces that are warmer than the surrounding areas. In India, for example, a low forms over the hot land during the summer months, but moves out over the warmer ocean when the land cools in winter. Lows of this type are semi-permanent, however, and are less significant to the pilot than the “migratory cyclones” or “cyclonic depressions” that form when unlike air masses meet. These lows will be discussed later.

5.1.3 Convection currents

Certain kinds of surfaces are more effective than others at heating the air directly above them. Plowed ground, sand, rocks, and barren land give off a great deal of heat, whereas water and vegetation tend to absorb and retain heat. The uneven heating of the air causes small local circulations called “convection currents,” which are similar to the general circulation just described.

This is particularly noticeable over land adjacent to a body of water. During the day, air over land becomes heated and less dense. The colder air over water moves in to replace it, which forces the warm air aloft and causes an on-shore wind. At night the land cools, and the water is relatively warmer. The cool air over the land then moves toward the water as an off-shore wind, lifting the warmer air and reversing the circulation.

Convection currents cause the bumpiness experienced by pilots flying at low altitudes in warmer weather. On a low flight over varying surfaces, the pilot will encounter updrafts over pavement or barren places and down drafts over vegetation or water. Ordinarily, this can be avoided by flight at higher altitudes. When the larger convection currents form cumulus clouds, the pilot will invariably find smooth air above the cloud level.

Convection currents also cause difficulty during landings since they affect the rate of descent. Figures 5-2 and 5-3 show what happens to an aircraft on a landing approach over two different terrain types. The pilot must constantly correct for these affects during the final approach to the airport.

The effects of local convection, however, are less dangerous than the turbulence caused when wind is forced to flow around or over obstructions. The only way for the pilot to avoid this invisible hazard is to be forewarned, and to know where to expect unusual conditions.

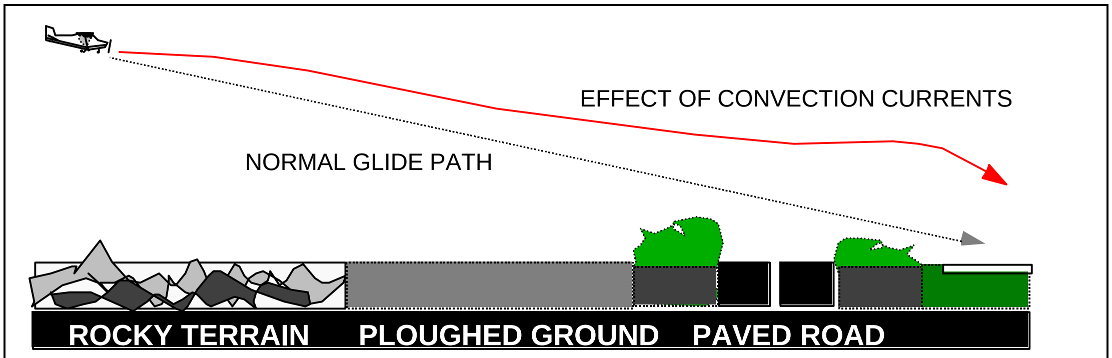


Figure 5-2

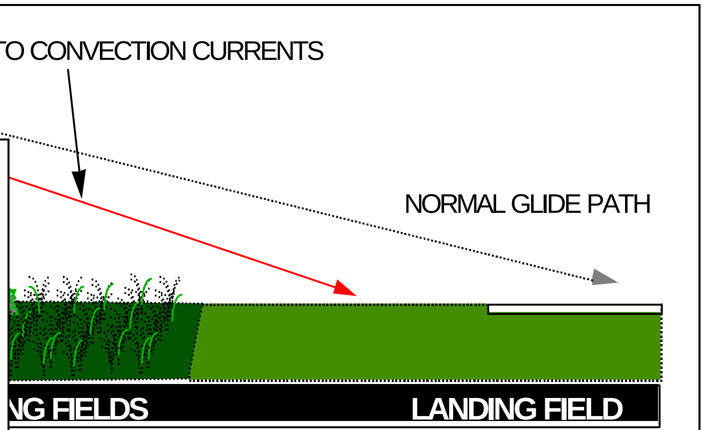
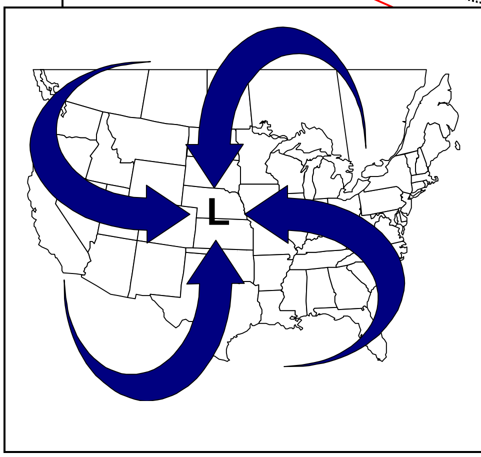


Figure 5-3



5.1.4 Effect of Obstructions on Wind

When the wind flows around an obstruction it breaks into eddies or gusts, with corresponding sudden changes in speed and direction. These effects may be felt some distance from the obstruction. The intensity of this turbulence depends on the size of the obstacle and the wind velocity, and it can present a serious hazard during takeoffs and landings. For example, during landings it can cause a pilot to “drop-in” and during takeoffs it can prevent the aircraft from gaining enough altitude to clear obstacles in its path. A pilot flying into such conditions must anticipate these effects and compensate accordingly.

This same condition is more noticeable where larger obstructions such as bluffs or mountains are involved. The wind blowing up the slope on the windward side is relatively smooth and its upward current helps to carry the aircraft over the peak. The wind on the leeward side, following the terrain contour, flows downward with considerable turbulence and would tend to force an aircraft into the mountain side. The stronger the wind, the greater the downward pressure and the accompanying turbulence. Consequently, in approaching a hill or mountain from the leeward side, a pilot should approach at a 45° angle and with enough altitude to safely clear the obstacle. Because of these downdrafts, it is recommended that mountain ridges and peaks be cleared by at least 2,000 feet. If there is any doubt about having adequate clearance, the pilot should turn away at once and gain altitude.

Between hills or mountains, where there is a canyon or narrow valley, the wind will generally veer from its normal course and flow through the passage with increased velocity and turbulence. A pilot flying in such terrain needs to be alert for wind shifts and particularly cautious when landing.

5.1.5 Winds around pressure systems

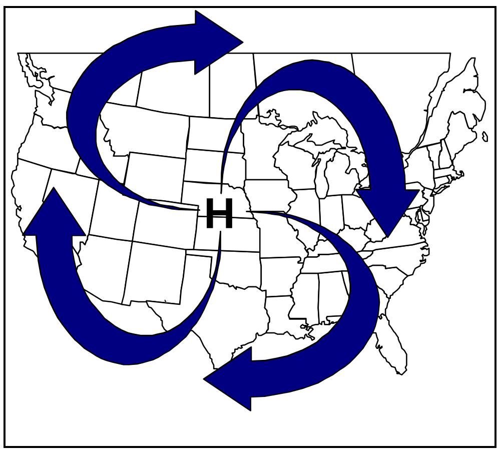
Certain wind patterns can be associated with areas of high and low pressure. As previously stated, air flows from areas of high pressure to areas of low pressure. In the Northern Hemisphere the air is deflected to the right because of the rotation of the earth. Therefore, as the air leaves the high-pressure area, it is deflected to produce a clockwise circulation. As the air flows toward low pressure it is deflected to produce a counterclockwise flow around the low-pressure area.

Another important aspect is that air moving out of a high depletes the quantity of air, creating an area of descending air. Since descending air favors the dissipation of clouds, highs are associated with good (clear) weather.

By similar reasoning, when air converges into a low-pressure area it cannot go outward against the pressure gradient, nor can it go downward into the ground; it must go upward. Rising air is conducive to cloudiness and precipitation, thus the general association of bad weather with lows.

Understanding these patterns frequently enables a pilot to plan a course to take advantage of favorable winds, particularly during long flights. In flying from east to west, for example, the pilot will find favorable winds to the south of a high, or to the north of a low. It also gives the pilot a general idea of the type of weather to expect relative to the "highs" and "lows."

5.2 Icing



5.2.1 Freezing level

As altitude increases, temperature decreases at the fairly uniform rate of 2° Celsius (3.6° F) per 1000 feet. This rate of temperature change is known as the *lapse rate*. At some altitude, the air temperature reaches the freezing temperature of water, and that altitude is known as the *freezing level*. You can estimate the freezing level prior to flight by using simple mathematics. For example, if the airport elevation is 1,000 feet and the temperature at ground level is 12° Celsius, the freezing level would be at approximately 6,000 feet above ground level (AGL) or 7,000 feet above mean sea level (MSL). Since the lapse rate is 2° per thousand feet, it would take 6,000 feet of altitude to go from 12° Celsius to 0°, the freezing temperature of water. The same technique works for Fahrenheit, but you use 3.6° for the lapse rate. Don't forget to include the airport elevation in your computations—altimeters are normally set to display MSL rather than AGL altitude. This method yields a very approximate value for the freezing level. You are encouraged to leave a wide margin for error above and below this altitude if you must fly through visible moisture during a search.

5.2.2 Airframe icing

When the ground cools at night, the temperature of the air immediately adjacent to the ground is frequently lowered to the saturation point, causing condensation. This condensation takes place directly upon objects on the ground as dew if the temperature is above freezing, or as frost if the temperature is below freezing.

Dew is of no importance to aircraft, but frost can be deadly. Normally we think of frost as unimportant -- it forms on cars or other cold surfaces overnight and usually melts after the sun rises. However, frost on an airfoil disturbs the airflow enough to reduce lift and efficiency. An airplane *may* be able to fly with frost on its wings, but even with the airflow over the wings only slightly disrupted, controllability can become unpredictable. **Frost should always be removed before flight.**

Ice can also accumulate on aircraft during flight, and this icing is a major problem. It is difficult to forecast, because under apparently identical situations the icing intensity on the aircraft can vary considerably. The ice accumulation rate may vary from less than one-half inch per hour to as high as one inch in a minute for brief periods. Experiments have shown that an ice deposit of one-half inch on the leading edge of some types of airfoil presently in use will reduce their lift by about 50%, increase the drag by an equal percentage, and greatly increase the stalling speed. Obviously, the consequences of ice accumulations can be very serious.

There are two fundamental requisites for ice formation on an aircraft. First, the aircraft must be flying through visible water in the form of rain or cloud droplets; and second, when the liquid water droplets strike, their temperature or the temperature of the airfoil surface must be 32 degrees F. or below. [Water droplets cooled below 32 degrees F. without freezing are called supercooled water droplets. They often exist in clouds when the temperature within the clouds is below 32 degrees F.]

Clear ice is a transparent or translucent coating of ice which has a glassy surface appearance. When transparent, it looks like ordinary ice, and is identical with the “glaze” which forms on trees and other objects when freezing rain falls to earth. It can be smooth or stippled. However, when mixed with snow, sleet, or hail it may be rough, irregular and whitish. It adheres very firmly to the surfaces upon which it forms and is very difficult to remove. Glaze usually forms on leading edges more or less in the shape of a blunt nose and spreads back, tapering along the wings. When deposited as a result of freezing of super-cooled raindrops or large cloud droplets unmixed with solid precipitation, it can be quite smooth and approximate a streamline form. When mixed with solid precipitation, the deposit can become especially blunt-nosed and rough, with heavy protuberances.

Rime ice is a white or milky, opaque, granular deposit of ice that accumulates on aircraft leading edges (including antennas) and projects forward into the air stream. Its surface is ordinarily rough. It has a granulated, crystalline or splintery structure. Wherever particles of supercooled water impinge on surface projections of the aircraft, such as rivet heads, the deposit acquires the form of a bulge which may cling rather firmly to the projecting parts.

When ice forms on an aircraft it can affect the flying characteristics in several ways:

- Lift is decreased. This is caused by a change in airfoil shape when ice accumulates on the leading edges. The aircraft will stall at air speeds well above the normal stalling speed.
- Weight is added. Clear ice can add substantial weight to an aircraft. The added weight increases lift requirements and increases drag. This is what makes the added weight of ice so dangerous.
- Drag is increased. This results when rough ice forms in back of the leading edges and on protuberances.

- Propeller efficiency is decreased. Uneven ice deposits on the blades cause vibration and blade distortion with consequent loss of effective power. Under icing conditions, all available power may be needed.

When flying in regions of possible icing condition, plan your flight so as to be in the region for the shortest possible time:

- Caution should be exercised when flying through rain or wet snow when the temperature at flight levels is near freezing.
- When flying into clouds above the crest of ridges or mountains, maintain a clearance of 4,000 or 5,000 feet above the ridges if the temperature within the cloud is below freezing. Icing is more probable over the crest of ridges than over the adjacent valleys.
- Watch for ice when flying through cumulus clouds when the temperature at flight level is near freezing.
- When ice forms on the aircraft, avoid maneuvers that will increase the wing loading.
- Remember that fuel consumption is greater when flying under icing conditions, due to increased drag and the additional power required.
- Consult the latest forecasts for expected icing conditions.

5.2.3 Carburetor icing

Although not directly related to weather, another problem is carburetor icing. As air is drawn through the carburetor venturi, it expands and cools. Moisture in the air can condense and freeze, blocking the flow of air and fuel to the engine.

Unlike aircraft structural icing, the aircraft does not need to be in visible moisture and the air temperature does not need to be near freezing for carburetor ice to form. Since it’s moisture in the air that condenses and freezes, airplanes are most vulnerable to carburetor icing when operated in high humidity. In the summer this can occur at altitudes below 10,000 feet with air temperatures as high as 77 degrees F.

Normally, an airplane engine develops sufficient heat at climb and cruise power settings to keep carburetor ice from forming. It's most likely to become a problem when the aircraft is operated at low power settings, such as in descents and approaches to landings.

Many manufacturers have provided a means for selectively ducting warm air to the carburetor to prevent icing when operating at low power settings. This feature is called *carburetor heat,* and the pilot may select it when starting a low-power descent. Fuel-injected engines are not vulnerable to carburetor icing.

5.3 Frontal activity

Large high-pressure systems frequently stagnate over large areas of land or water with relatively uniform surface conditions. They take on characteristics of these “source regions” -- the coldness of polar regions, the heat of the tropics, the moisture of oceans, or the dryness of continents.

As air masses move away from their source regions and pass over land or sea, they are constantly being modified through heating or cooling from below, lifting or subsiding, absorbing or losing moisture. Actual temperature of the air mass is less important than its temperature in relation to the land or water surface over which it is passing. For example, an air mass moving from polar regions is usually colder than the land and sea surfaces over which it passes. On the other hand, an air mass moving from the Gulf of Mexico in winter usually is warmer than the territory over which it passes.

If the air is colder than the surface, it will be warmed from below and convection currents will be set up, causing turbulence. Dust, smoke, and atmospheric pollution near the ground will be carried upward by these currents and dissipated at higher levels, improving surface visibility. Such air is called “unstable.” Conversely, if the air is warmer than the surface, there is no tendency for convection currents to form and so the air is smoother. Smoke, dust, and pollution are concentrated at lower levels with resulting poor visibility. Such air is called “stable.” From the combination of the source characteristics and the temperature relationship just described, air masses can be associated with certain types of weather.

Characteristics of a cold, unstable air mass are:

- cumulus and cumulonimbus clouds.
- unlimited ceilings (except during precipitation).
- excellent visibility (except during precipitation).
- pronounced turbulence in lower levels because of convention currents.
- occasional local thunderstorms or showers, hail, sleet, and snow flurries.

Characteristics of a warm, stable air mass are:

- stratus and stratocumulus clouds.
- generally low ceilings, fog, haze.
- poor visibility (smoke and dust held in lower levels).
- smooth air with little or no turbulence.
- slow steady precipitation or drizzle.

When two air masses meet they will not mix readily unless their temperatures, pressures, and relative humidities are very similar. Instead, they set up boundaries called frontal zones, or “fronts.” The colder air mass projects under the warmer air mass in the form of a wedge.

Usually the boundary moves along the earth's surface, and as one air mass withdraws from a given area it is replaced by another air mass. This action creates a moving front. If warmer air is replacing colder air, the front is called “warm”; if colder air is replacing warmer air, the front is called “cold.” If the boundary is not moving, it is termed a “stationary front.”

5.3.1 Warm Front

When a warm front moves forward, the warm air slides up over the wedge of colder air lying ahead of it.

Warm air usually has high humidity. As this warm air is lifted its temperature drops. Condensation occurs as the lifting process continues, nimbostratus and stratus clouds form, and drizzle or rain develops. The rain falls through the colder air below, increasing its moisture content so that it also becomes saturated. Any reduction of temperature in the colder air, which might be caused by up-slope motion or cooling of the ground after sunset, may result in extensive fog.

In stable air as the warm air progresses up the slope with constantly falling temperature, clouds appear at increasing heights in the form of altostratus and cirrostratus. If the warm air is unstable, cumulonimbus clouds and altocumulus clouds will form and frequently produce thunderstorms. Finally, the air is forced up near the stratosphere, and in the freezing temperatures at that level the condensation appears as thin wisps of cirrus clouds. This up-slope movement is very gradual, rising about 1,000 feet every 20 miles. Thus cirrus clouds, forming at perhaps 25,000 feet, may appear as far as 500 miles in advance of the point on the ground which marks the position of the front.

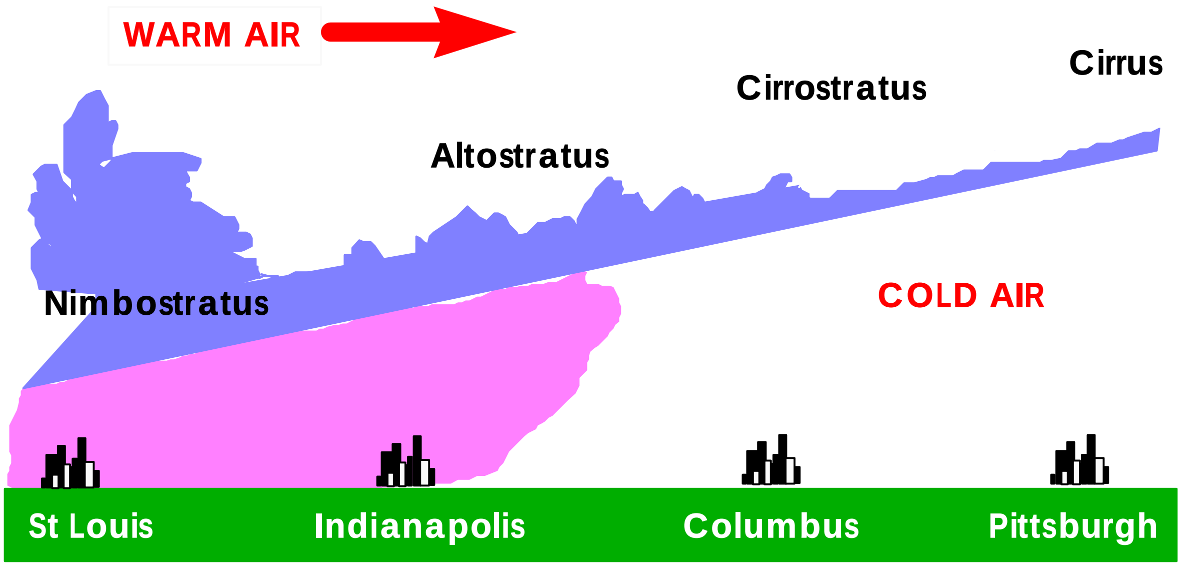
Warm fronts generally move at the rate of 10 to 25 miles an hour.

5.3.2 Flight toward an approaching warm front

Although no two fronts are exactly alike, a clearer understanding of the general weather pattern may be gained by looking at the conditions which might exist when a warm front is moving eastward from St. Louis, Mo.:

- In St. Louis the weather would be unpleasant, with drizzle and possibly fog.
- At Indianapolis, Ind., 200 miles in advance of the warm front, the sky would be overcast with nimbostratus clouds, and continuous rain.
- At Columbus, Ohio, 400 miles in advance, the sky would be overcast with predominantly stratus and altostratus clouds. A steady rain is likely.
- At Pittsburgh, Pa., 600 miles ahead of the front, there would probably be high cirrus and cirrostratus clouds.

If you flew from Pittsburgh towards St. Louis, ceiling and visibility would decrease steadily. Starting under bright skies with unlimited ceilings and visibilities, lowering stratus-type clouds and precipitation would be encountered as you approached Columbus. By the time you reached Indianapolis the ceilings would be too low for further flight, and precipitation may have reduced visibility to practically zero. Thus you would have to remain in Indianapolis until the warm



front passes, which might take a day or two.

On the trip from Pittsburgh to Indianapolis you would notice a gradual increase in temperature and a much faster increase in dew point, until the two coincided. Also, the atmospheric pressure would be gradually lessening because the warmer air aloft would have less weight than the colder air it was replacing. This condition illustrates the general principle that a falling barometer indicates the approach of stormy weather.

If you wanted to fly from St. Louis to Pittsburgh, it would be best to wait until the front had passed beyond Pittsburgh. This might take three or four days.

5.3.3 Cold Front

When the cold front moves forward it acts like a snow plow, sliding under the warmer air and forcing it aloft. This cools the warm air and forms clouds (cloud type depends upon whether the warm air is stable or unstable).

The slope of a cold front is much steeper than that of a warm front and its progress is generally more rapid -- usually from 20 to 35 miles per hour. In extreme cases, cold fronts have been known to move at 60 miles per hour. Cold fronts rush in almost unannounced, make a complete change in the weather within a period of a few hours, and moves on.

In these fast-moving fronts, friction retards the front near the ground and brings about a steeper frontal surface. This steep frontal surface results in a narrower band of weather concentrated along the forward edge of the front. If the warm air is stable, an overcast sky may occur for some distance ahead of the front, accompanied by general rain. If the warm air is unstable, scattered thunderstorms and showers may form. Altostratus clouds sometimes form slightly ahead of the front, bur these are seldom more than 100 miles in advance.

At times, an almost continuous line of thunderstorms may form along the front or ahead of it. These lines of thunderstorms (squall lines) contain some of the most turbulent weather experienced by pilots. Weather clears rapidly behind a fast-moving cold front, although gusty and turbulent surface winds and colder temperatures prevail.

This weather activity is more violent than that associated with warm fronts, and usually takes place directly at the front instead of occurring in advance of the front. In late afternoon during the warm season, however, squall lines frequently develop as much as 50 to 200 miles in advance of the actual cold front. Whereas warm front dangers are low ceilings and visibilities, cold front dangers are chiefly sudden storms, high and gusty winds, and turbulence.

5.3.4 Flight toward an approaching cold front

If a flight was made from Pittsburgh toward St. Louis when a cold front was approaching from St. Louis, weather conditions quite different from those associated with a warm front will be experienced. The sky in Pittsburgh would probably be somewhat overcast with the stratocumulus clouds typical of a warm air mass. The air would be smooth, with relatively low ceilings and visibility.

As the flight proceeded, these conditions would prevail until reaching Indianapolis. At this point it would be wise to check the position of the cold front. It would probably be about 75 miles west of Indianapolis. A pilot familiar with frontal systems would remain in Indianapolis until the front had passed -- a matter of a few hours -- and then continue to the destination under near perfect flying conditions.

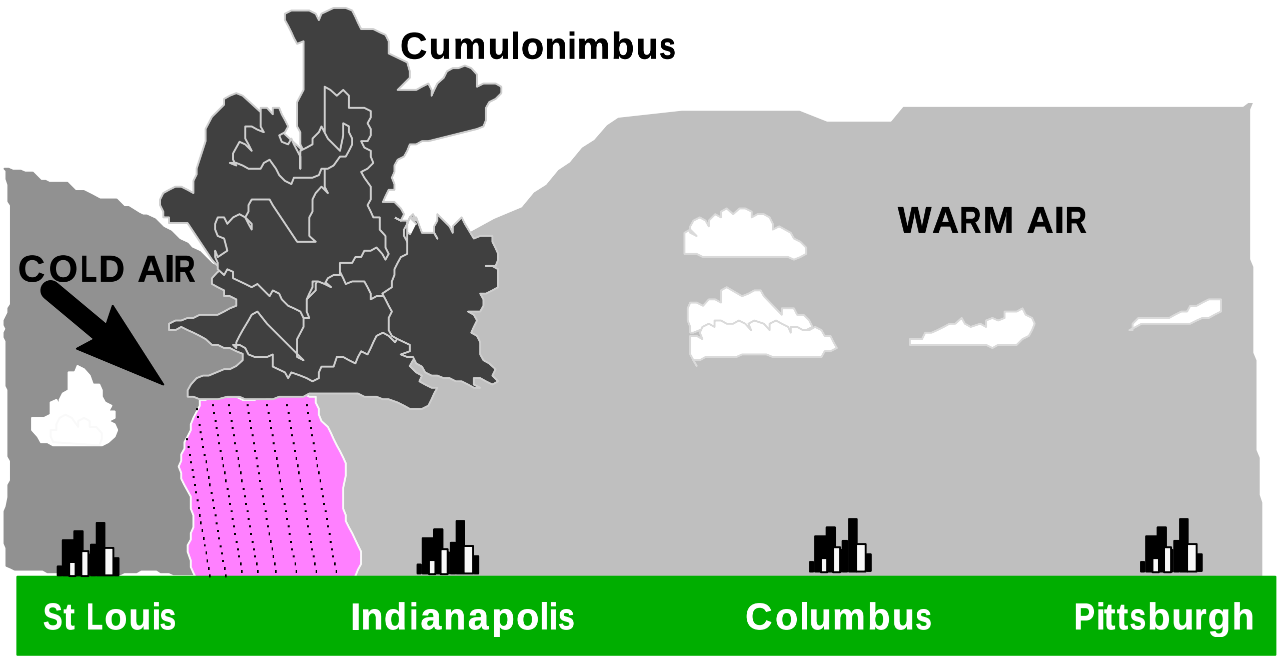
However, assume the pilot continued toward the approaching cold front. He would see a few altostratus clouds with a dark layer of nimbostratus lying low on the horizon, and perhaps cumulonimbus in the background. Two courses would now be open:

- Either turn around and outdistance the storm, or
- Make an immediate landing, which might be extremely dangerous because of gustiness and sudden wind shifts (wind shear).

If, however, the flight was continued, the pilot would be trapped in a line of squalls and cumulonimbus clouds. It is impossible (in a small plane) to fly above thunderstorms, and it is usually disastrous to try and fly beneath them. At low altitudes there are no safe passages through the squalls, and there is usually little chance of flying around them because they often extend in a line for 300 to 500 miles.

5.3.5 Occluded Front

One other form of front is the “exclusion” or “occluded front.” This is a



condition in which an air mass is trapped between two colder air masses and forced aloft to higher and higher levels, until it finally spreads out and loses its identity. An occluded front appears on weather maps as shown in Figure 5-4.

Meteorologists subdivide occlusions into two types, but, so far as the pilot is concerned, the weather in any occlusion is a combination of warm front and cold front conditions. As the occlusion approaches, the usual warm front indications prevail -- lowering ceilings, lowering visibility, and precipitation. Generally, the warm front weather is then followed almost immediately by cold front weather, with its squalls, turbulence, and thunderstorms.

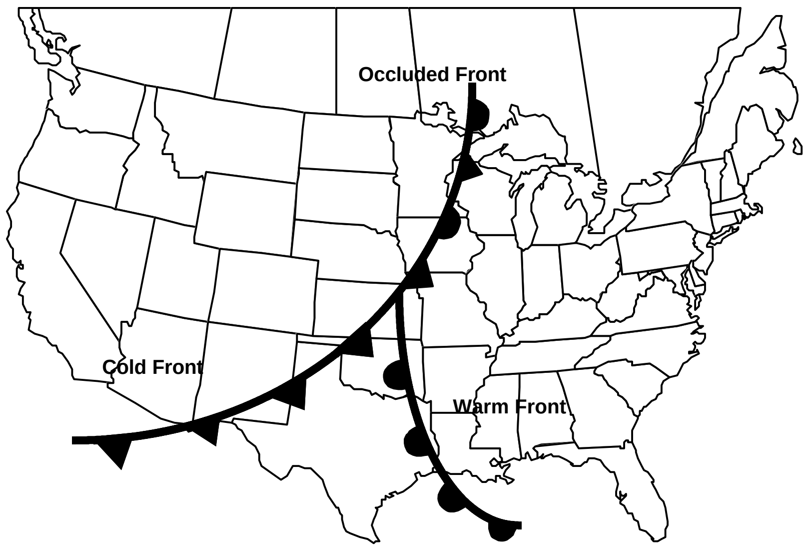


Figure 5-4

Reduced Visibility

According to FAA regulations, under almost all circumstances, flight using visual flight rules (VFR) can only be conducted with at least three miles of visibility. If more than one-half the sky is covered by clouds, the cloud bases must be no lower than 1,000 feet above the terrain. In addition, the VFR pilot must remain clear of all clouds.

One of the most common hazardous-weather problems is loss of visibility. This can happen suddenly or very insidiously, depriving the pilot of his ability to see and avoid other aircraft and reducing or depriving him altogether of his ability to control the aircraft, unless he has had training and is proficient in instrument flying. In reduced visibility, the crew's ability to see and avoid towers, power transmission lines, and other man-made obstacles is diminished (not to mention the problems it causes in finding your target).

Visibility is reduced by conditions such as clouds, rain, snow, fog, haze, smoke, blowing dust, sand, and snow. A similar condition called “white out” can occur where there has been snowfall.

In most regions of the country, fog and haze are the most common weather conditions that cause reduced visibility. Fog, especially dense fog, can pose a hazard to even the most sophisticated military or civilian aircraft. In thick fog, reduced visibility may make it extremely difficult, if not impossible, to see landing runways or areas. The crew should be alert for a potential problem with fog whenever the air is relatively still, the temperature and dew point are within several degrees, and the temperature is expected to drop further (e.g., around sunset or shortly after sunrise).

Haze, a fine, smoke-like dust, causes lack of transparency in the air. It’s most often caused when still air prevents normal atmospheric mixing. If the wind remains calm for several days, visibility will become progressively worse. This atmospheric condition is most common in heavily populated, industrialized areas of the country. It can also be present anywhere there is still air and a source of particles, like burning farm fields or thick forests that produce large quantities of pollen. It is especially noticeable in the early morning.

Frequently, as the sun warms the cool, hazy air and causes it to expand and rise, visibility at the surface will improve and appear acceptable. What initially appeared to be ample visibility can, after takeoff, become almost a complete obstruction to lateral or forward visibility several hundred feet above the surface. Downward visibility is satisfactory, but pilots may feel apprehensive about the loss of a visible horizon to help judge aircraft control, and about what might come out of the murk ahead. Visibility at this altitude may actually be more than the minimum three miles, yet the pilot may interpret this visual range as a wall just beyond the airplane's nose.

In summer, haze and smoke may extend upward more than 10,000 feet during the heat of the day. This presents a special hazard as it can hide rain showers or thunderstorms. When haze and smoke are present, the best action a flight crew can take to minimize this risk is to get a thorough weather briefing before flying and update the briefing during the flight.

Blowing dust is normally found in the relatively dry areas of the country, like the desert southwest. The condition develops when strong wind picks up small soil particles and air currents carry it upward into the atmosphere. These conditions can spread dust hundreds of miles and up to 15,000 feet. Depending upon wind speed and particle volume, visibility in dust storms may be reduced to very low levels. Blowing sand is much more localized than dust, occurring only when the wind is strong enough to lift loose sand. Since sand particles are much heavier than dust, sand is seldom lifted more than 50 feet above the surface. Still, the condition eliminates the effectiveness of visual searches, and in many cases can prohibit an aircraft from taking off or landing.

Strong surface winds can also cause blowing snow. Blowing snow is more frequent in areas where dry, powdery snow is found. For the aviator, blowing snow can cause the same problems of reduced visibility. Like dust, it can reach thousands of feet above the surface.

Snow can cause another visibility problem, known as “white out.” This condition can occur anywhere there is snow-covered ground, but is most common in arctic regions. It's not a physical obstruction to visibility like earlier examples, but an optical phenomenon. White out requires a snow-covered surface and low-level clouds of uniform thickness. At low sun angles, light rays are diffused as they penetrate the cloud layer causing them to strike the snow-covered surface at many angles and eliminating all shadows. The net effects are loss of a visible horizon and loss of depth perception, each of which can make low-level flight and landings difficult and hazardous.

5.5 Turbulence

Turbulence is irregular atmospheric motion or disturbed wind flow, and can be attributed to a number of causes. Under almost all circumstances, small amounts of normal atmospheric turbulence can be expected and it usually poses few problems. Previous sections covered wake turbulence and convective activity as causes of turbulence. Convective activity was covered in the context of thunderstorm development, but any phenomenon that causes air to be lifted up -- even a hot asphalt parking lot -- can cause turbulence. Other causes include obstructions to wind flow and wind shear.

Just as a tree branch dangling into a stream creates continuous ripples or waves of turbulence in the water's surface, obstructions to the wind can create turbulence in the air. This type of turbulence usually occurs close to the ground, although it may reach upward several thousand feet, depending upon wind velocity and the nature of the obstruction. In an extreme case, when winds blow against a mountainside the mountain deflects the wind upward, creating a relatively smooth updraft. Once the wind passes the summit, it tumbles down the leeward or downwind side, forming a churning, turbulent down draft of potentially violent intensity. The churning turbulence can then develop into *mountain waves* that may continue many miles from the mountain ridge. Mountain waves may be a factor when surface winds are as little as 15 knots.

Turbulence can be inconsequential, mildly distracting, nauseating, or destructive depending on its intensity. Turbulence can often be avoided by changing altitudes.

Aircraft manufacturers publish *maneuvering speeds* in the operating handbooks. If the maneuvering airspeed of an aircraft is exceeded in turbulent air, structural damage could occur.

5.6 Wind, windshear and mountain wave

Windshear is best described as a change in wind direction and/or speed within a very short distance. Under certain conditions, the atmosphere is capable of producing some dramatic shears very close to the ground; for example, wind directional changes of 180 degrees and speed changes of 50 knots or more within 200 feet of the ground have been observed. This, however, is not something encountered every day. In fact it is unusual, which makes it more of a problem. It has been thought that wind can not affect an aircraft once it is flying except for drift and groundspeed. This is true with steady winds or winds that change gradually. It isn't true, however, if the wind changes faster than the aircraft mass can be accelerated or decelerated.

The most prominent meteorological phenomena that cause significant low-level windshear problems are thunderstorms and certain frontal systems at or near an airport.

Basically, there are two potentially hazardous shear situations: 1) a tailwind may shear to either a calm or headwind component. Initially the airspeed increases, the aircraft pitches up, and the altitude increases. 2) a headwind may shear to a calm or tailwind component. Initially the airspeed decreases, the aircraft pitches down, and the altitude decreases. Aircraft speed, aerodynamic characteristics, power/weight ratio, power plant response time, pilot reactions and other factors have a bearing on wind shear effects. It is important, however, to remember that shear can cause problems for any aircraft and any pilot.

There are two atmospheric conditions that cause the type of low-level wind shear discussed herein: thunderstorms and fronts.

The winds around a thunderstorm are complex. Windshear can be found on all sides of a cell. The wind shift line or gust front associated with thunderstorms can precede the actual storm by up to 15 nautical miles. Consequently, if a thunderstorm is near an airport of intended landing or takeoff, low-level wind shear hazards may exist.

While the direction of the winds above and below a front can be accurately determined, existing procedures do not provide precise and current measurements of the height of the front above an airport. The following is a method of determining the approximate height of the front, with the consideration that wind shear is most critical when it occurs close to the ground.

- A cold front windshear occurs just after the front passes the airport and for a short period thereafter. If the front is moving 30 knots or more, the frontal surface will usually be 5,000 ft. above the airport about 3 hours after the passage.
- With a warm front, the most critical period is before the front passes the airport. Warm front shear may exist below 5,000 ft. for approximately 6 hours; the problem ceases to exist after the front passes the airport. *Data compiled on windshear indicate that the amount of shear in warm fronts is much greater than that found in cold fronts*.
- Turbulence may or may not exist in windshear conditions. If the surface wind under the front is strong and gusty, there will be some turbulence associated with windshear.

The pilot should be alert to the possibilities of low-level windshear any time the conditions discussed are present.

5.7 Thunderstorms

A thunderstorm is any storm accompanied by thunder and lighting. It usually includes some form of precipitation, and can cause trouble for aircraft in many forms: turbulence, icing, poor visibility, hail, wind shear, microbursts, lightning, and, in severe cases, tornadoes.

Individual thunderstorms may often be very local in nature, although they often form along weather fronts and appear to march across the land in long lines. This is the situation when weather forecasters announce that a line of thunderstorms is approaching, and thunderstorm warnings go into effect. Individual thunderstorms are rarely larger than 10 miles in diameter, and typically develop, mature, and dissipate within an hour and a half at the most. Each is produced by the growth of a puffy cumulus cloud into a cumulonimbus cloud. The severe elements of a thunderstorm result from the vertical air movement, or convective activity, within the storm.

Thunderstorms may be studied by dividing them into three separate growth stages: the (cumulus) building stage, the mature stage, and the dissipating stage. Figure 5-5 demonstrates the physical appearances of each stage of the developing storm.

Most cumulus clouds do not become thunderstorms, but all thunderstorms are born as cumulus clouds. The main feature of this first stage of thunderstorm development is its updraft, a large air current flowing upward from the ground through the chimney-like cloud. The draft can reach speeds of several thousand feet per minute, and continue to an altitude of 40,000 feet or more. During this period, small water droplets grow into raindrops as the cloud builds upward to become a cumulonimbus cloud.

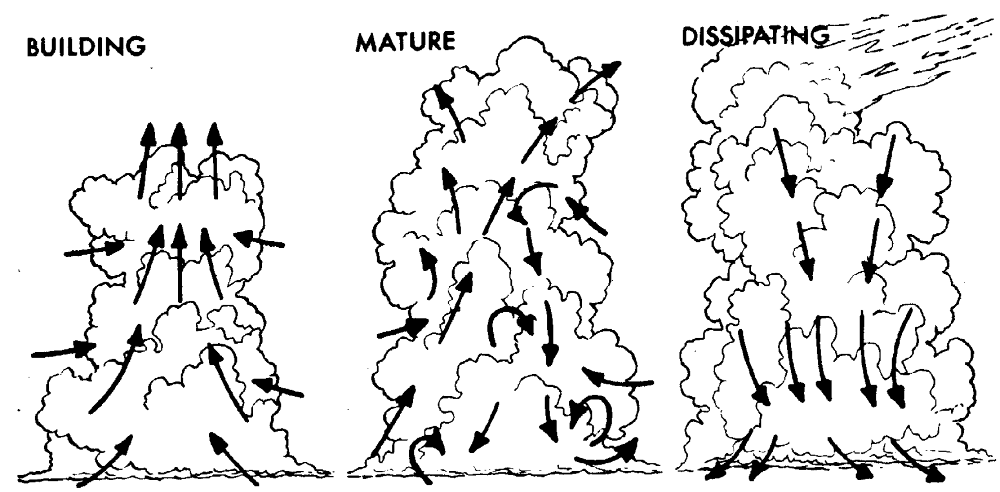


Figure 5-5

Precipitation at the earth's surface marks the mature stage of a thunderstorm. The raindrops (or ice particles) have now become so large and heavy that the updraft can no longer support them, and they begin to fall. As they fall, the raindrops drag air with them, causing the characteristic strong down draft of mature thunderstorms. These down drafts spread out horizontally when they reach the surface, producing strong, gusty winds, wind shear, sharp drops in temperature (because the air was chilled at high altitudes) and a sharp rise in pressure.

The mature stage of the thunderstorm is when associated hazards are most likely to reach maximum intensity. Microbursts, extremely intense down drafts, can occur during this mature phase of development. Downward wind velocities in microbursts *may reach 6,000 feet per minute*, and even powerful jet aircraft may have insufficient power to recover prior to ground impact.

As down drafts continue to spread the updrafts weaken, and the entire thunderstorm eventually becomes an area of down drafts. This characterizes the dissipating stage of the thunderstorm. During this stage, the cloud develops the characteristic anvil shape at the top and may take on a stratiform or layered appearance at the bottom. Usually this stage is the longest of the three stages of a thunderstorm's life.

No thunderstorm should ever be taken lightly. During the cumulus stage, vertical growth occurs so quickly that climbing over the developing thunderstorm is not possible. Flight beneath a thunderstorm, especially in the mature stage, is considered very foolish, due to the violent down drafts and turbulence beneath them. Flight around them may be a possibility, but can still be dangerous. Even though the aircraft may be in clear air, it may encounter hail, lightning, or turbulence a significant distance from the storm's core. Thunderstorms should be avoided by at least 20 miles laterally. The safest alternative, when confronted by thunderstorms, is to land, hanger or tie-down the aircraft, and wait for the storms to dissipate or move on.